STANDARDS DEVELOPMENT BRANCH OMOE
36936000010282

upper credit river

an evaluation of the natural self-purification capacity of the upper credit river

ONTARIO WATER RESOURCES COMMISSION

1967

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Wastewater assimilation study :
Upper Credit river.

80578

S. C Irwin - 859-0706
Nobleton

WASTEWATER ASSIMILATION STUDY

UPPER CREDIT RIVER

1967

ONTARIO WATER RESOURCES COMMISSION

PREFACE

The entire Credit watershed and the upper reaches in particular rank high among the scenic areas of Southern Ontario. Several parks have been developed mainly by the Credit Valley Conservation Authority, and certainly many more will be developed in the years to come. Plans have been prepared for the construction of several multiple-use reservoirs, two of which will be developed upstream from the Forks, one north of Orangeville and the other north of Cataract, on the main branch.

In this report a rational evaluation of the effects on water quality by the increasing use of the upper Credit River as a wastewater receiving stream is made. Chemical, bacteriological and biological parameters were utilized in the assessment of water quality. The self-purification capacity of the stream downstream from Orangeville is estimated in order to forecast the effects of wastewater loadings on the dissolved oxygen resources of the stream during summer drought flows and temperatures. This information is used to establish the required extent of wastewater treatment programs at Orangeville.

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CHAPTER I

CONCLUSIONS

RECOMMENDATIONS

CHAPTER I

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. The July 1966 survey revealed serious water quality impairment downstream from the Orangeville WPCP to the Hamlet of Melville. The Credit River data indicated excessive organic, nutrient, and bacterial concentrations. The dissolved oxygen content was found to be depleted.

2. Biological sampling throughout the three mile stretch downstream from Orangeville produced evidence of a preponderance of those invertebrate species that are tolerant to an organically enriched environment with reduced oxygen tension. Additionally, fish life was eliminated immediately downstream from the sewage plant and limited to pollution tolerant forms further downstream. Near the confluence of the Alton branch normal aquatic life including trout was encountered.

3. Factors contributing to low oxygen levels in the river were:

a) A large U-shaped beaver dam just upstream from the WPCP. The vast quantities of accumulated decomposing vegetation had depleted almost entirely the dissolved oxygen in the impounded water.

b) A beaver dam located approximately two miles downstream from the plant and numerous natural and man-made obstructions.

c) The low gradient and related sluggish flows.

4. The following wastewater loading limitations would apply at the 4.0 and 5.0 ppm, dissolved oxygen objectives in the receiving stream under both unaugmented (pre- reservoir construction) and augmented flow conditions.

HYDRAULIC LOAD OF STP	STREAM FLOW (cfs)	ACCEPTABLE BOD_5 LOAD (lbs. per day) IN STREAM FOR MINIMUM D.O. OF		
		4 ppm		5 ppm
0.75 MGD	Unaugmented 7-day low flow T=20 years-0.128 cfs/sq. mi.	72	(includes 10 lbs. of natural BOD_5 in stream)	0
0.75 MGD	10 cfs*	260	(includes 60 lbs. of natural BOD_5 in stream)	150
1.5 MGD	10 cfs*	285	(includes 60 lbs. of natural BOD_5 in stream)	153

* Augmented design flow
(for reservoir under construction)

Thus, under unaugmented flow conditions and assuming a stream objective of 4.0 ppm dissolved oxygen, the loading from the plant should be limited to about 60 pounds a day. With modification of the existing plant to a capacity of 0.75 mgd complete secondary, operation of the plant at a reliable 95 per cent efficiency will meet the 60 pound loading limit. This limitation would apply until the reservoir is completed and operating.

With completion of the storage reservoir to provide a reliable summer flow, it will be possible to achieve the 5.0 ppm objective providing the total plant loading does not exceed 90 pounds BOD_5 per day. Continued expansion of the treatment facilities should take the above loading limitations into account.

5. Future uses, particularly the development of multiple-use reservoirs downstream from Orangeville, will require the control of nutrient inputs to the river.

RECOMMENDATIONS

1. The beaver dam upstream from Orangeville WPCP should be removed and an unrestricted flow condition maintained.

2. The dissolved oxygen content of the waters in the upper Credit River should be maintained at a level of 5.0 ppm.

3. With completion of the flow augmentation project above Orangeville, future sewage works operations and planning should be guided by the design limitations that would ensure a minimum average dissolved oxygen value of 5.0 ppm in the receiving stream. This can be accomplished by limiting the loading from the plant to about 90 pounds BOD_5 per day.

CHAPTER II

INTRODUCTION

CHAPTER II

INTRODUCTION

1. GEOGRAPHY AND PHYSIOGRAPHY

The Credit River flows through sedimentary bedrocks belonging to the Ordovician and Silurian eras. Kame moraines are found in the upper watershed and identified by stratified gravelly and sandy materials and water-smoothed stones. The Orangeville Sandy Hills are kame moraines which are characterized by rough topography, sandy soil materials, and flat-bottomed swampy valleys.

The Credit River rises in the northwest corner of the watershed at 1,425 feet above sea level and flows at an average gradient of 21 feet per mile to its confluence with Lake Ontario. Although the Credit River flow in the areas of the Credit Forks and Streetsville is rapid, the gradient in the survey area below Orangeville is approximately 5.0 feet per mile, resulting in a slow, quiescent flow.

2. CLIMATE

Within the watershed three climatic regions can be distinguished: the Lake Shore, the Peel Plain and the Upland Regions. The Upland Region, which includes the land north of the Niagara Escarpment, is cooler, has more precipitation, shorter summers, and longer winters than the other regions. It has a mean annual temperature of 42°F, and an annual precipitation of about 36 inches.

3. STREAMFLOW

The Federal Department of Energy, Mines and Resources operates a recording flow gauge at Cataract (2HB1). These data are available from the year 1920, and were utilized to make drought flow predictions (Appendix B).

4. STREAM CHARACTERISTICS

The Credit River meanders through a tree-covered sometimes steep-sided valley in a well defined channel. Exceptions are those areas affected by flow obstructing beaver dams and the dam located between Stations 15 and 16. The beaver dam located approximately 2300 feet downstream from Station 1 backs up water covering a 15 acre area.

Sludge accumulations up to 2.5 feet deep consisting primarily of rotting vegetation were observed behind this dam and found to have a significantly depressing effect on dissolved oxygen concentrations. A second beaver dam (200 feet upstream from Station 9) floods approximately 20 acres of land and backwater effects were noticeable one half mile upstream from the dam. Sludge accumulations again were found behind this dam. Other obstructions in the stream, although of less serious nature with regard to adverse effects on water quality, include fallen trees, large branches and tree roots.

5. WATER SUPPLY AND WASTEWATER DISPOSAL

Water supply for municipal purposes and livestock watering, wastewater disposal, and recreation appear to be the major uses of the river. The Town of Streetsville (44 miles downstream from Orangeville) obtains its municipal supply from the Credit River. A 0.75 mgd. water pollution control plant operated by the OWRC serves the Town of Orangeville. Primary treatment is provided to the entire sewage flow with approximately 20 per cent receiving conventional activated sludge treatment. The plant effluent is chlorinated. A number of private outfalls discharge to the West branch of the Credit River flowing easterly through Orangeville.

CHAPTER III

WASTEWATER ASSIMILATION

CHAPTER III

WASTEWATER ASSIMILATION

1. INTRODUCTION

A modification of the Streeter-Phelps theory of analysis of the decay of organic pollutants in streams was used to establish the relationship between the addition of oxygen-consuming pollutants and resulting water quality conditions.

A detailed evaluation of the wastewater input at Orangeville was made. Based on the assumption that the wastewater discharge receives thorough mixing in the stream to produce uniformity over its cross-section, a one dimensional analysis along the longitudinal axis was made.

Survey station locations were defined by stream mileage and time of travel.

Mean water temperatures derived from survey data were employed in calculations dealing with oxygen, and rates of deoxygenation and re-oxygenation.

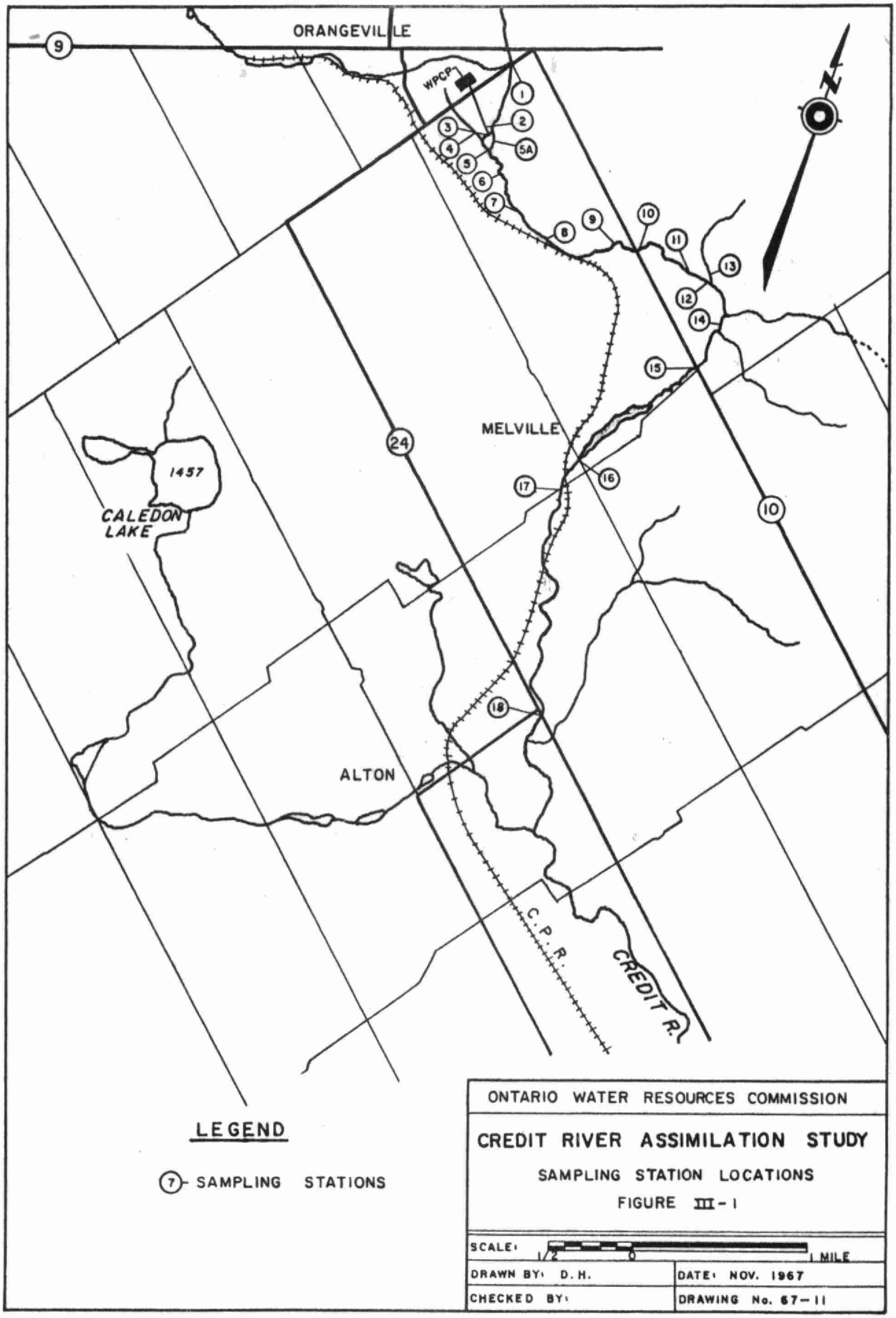
It was assumed that the organic pollutants decayed in accordance with first order kinetics. The coefficient of BOD removal, Kr, combines BOD removal by biochemical oxidation, absorption, adsorption or deposition. This coefficient defines the distribution of BOD but not the oxygen utilization pattern since some of the above factors remove BOD without the associated usage of oxygen. To relate BOD removal to the rate of oxygen utilization, the coefficient Kd was determined. This coefficient represents BOD reduction by biochemical oxidation only. For the evaluation of the two coefficients no distinction was made between the carbonaceous and nitrogenous phases of the biochemical oxidative process.

In the assessment of the coefficient of reoxygenation, K_2, oxygen sources as atmospheric reaeration, photosynthesis, oxygen contained in tributary water, etc. are combined and no distinction was made between these sources.

2. FIELD SURVEY

Eighteen sampling stations were established commencing at the bridge on the Town Line just west of Highways 9 and 10 and extending to Highway 24 east of Alton. Survey station locations are illustrated in Figure III-1 and described in Table III-1.

The field work required two 4-man crews working 12-hour shifts from July 18 to July 20, 1966. At four hour intervals water samples for BOD_5 analysis were taken, and field dissolved oxygen, temperature and streamflow were measured. Samples for complete chemical analysis and bacteriological examination were taken midway through the survey. Samples of the raw sewage and the WPCP effluent were composited over 12 hour periods. Time of travel was established using Rhodamine WT dye and a fluorometer, and by cross-sectioning.



ONTARIO WATER RESOURCES COMMISSION

CREDIT RIVER ASSIMILATION STUDY

SAMPLING STATION LOCATIONS

FIGURE III - 1

SCALE: 1/2 0 1 MILE

DRAWN BY: D. H.

DATE: NOV. 1967

CHECKED BY:

DRAWING No. 67-11

TABLE III-I

SAMPLING STATION LOCATIONS (SEE FIGURE III-I)

STATION	MILEAGE	LOCATION	DRAINAGE AREA	DISTANCE FROM W.P.C.P.
1	CR 53.6	Bridge on Town Line just west of Highway #10	15.0	0.4 miles
2	CR 53.2	Just upstream of the WPCP discharge (west stream below Beaver Dam)	N.A.	50 feet
WPCP	CR 53.2		N.A.	0.0 miles
3	CR 53.15	250 feet downstream of the WPCP discharge	15.2	0.05 miles
4*	CRT 53.3	Small tributary at the S-E corner of the Town at the Town limit	0.05	N.A.
5	CR 53.0	2200 feet downstream of the WPCP discharge	15.3	0.2 "
5A	CR 53.2	East stream 200 feet below Beaver Dam	N.A.	N.A.
6	CR 52.9	100 feet downstream of the confluence of east and west streams	15.6	0.3 "
7	CR 52.6	Remains of abandoned railroad bridge	17.2	0.6 "
8	CR 52.4	1000 feet below abandoned railroad bridge	17.7	0.8 "
9	CR 52.1	200 feet downstream Beaver Dam	17.8	1.1 "
10	CR 52.0	Highway #10 bridge	18.0	1.2 "
11	CR 51.6	1200 feet upstream from Station 12	18.1	1.6 "
12	CR 51.4	Privately-owned bridge	18.2	1.8 "
13*	CRT 51.3	300 feet downstream spillway of a newly built pond	1.83	N.A.
14	CR 51.2	1200 feet downstream of Station 12	21.2	1.9 "
15	CR 51.0	Highway #10 bridge	25.1	2.2 "
16	CR 50.0	At the dam 300 feet upstream of the 2nd Concession of Caledon Township	27.2	3.2 "
17	CR 49.7	Downstream of the Hamlet of Melville	28.1	3.5 "
18	CR 48.2	Third Concession Caledon Township	29.1	5.0 "

* TRIBUTARIES

N.A. - NOT APPLICABLE

3. SELF-PURIFICATION COEFFICIENTS

The following values for the coefficients of BOD removal and re-oxygenation were established and used throughout the survey area.

Section 1	Section 2
Kr = 2.62 per day @ 18.5°C	Kr = Kd = 0.78 per day @ 18.5°C
Kd = 0.78 per day @ 18.5°C	K_2 = 0.70 per day @ 18.5°C
K_2 = 0.70 per day @ 18.5°C	

The calculated dissolved oxygen profile using the above coefficients closely agreed with the observed dissolved oxygen profile. (Figure III-2).

4. CALCULATION OF ACCEPTABLE ORGANIC LOAD

The purpose of this section is to determine the maximum organic load that could be discharged to the river during critical summer temperatures and low flows. Dissolved oxygen objectives of 4.0 ppm and 5.0 ppm were considered, the latter objective applicable where use is made of the river for game fishing.

The following assumptions were made:

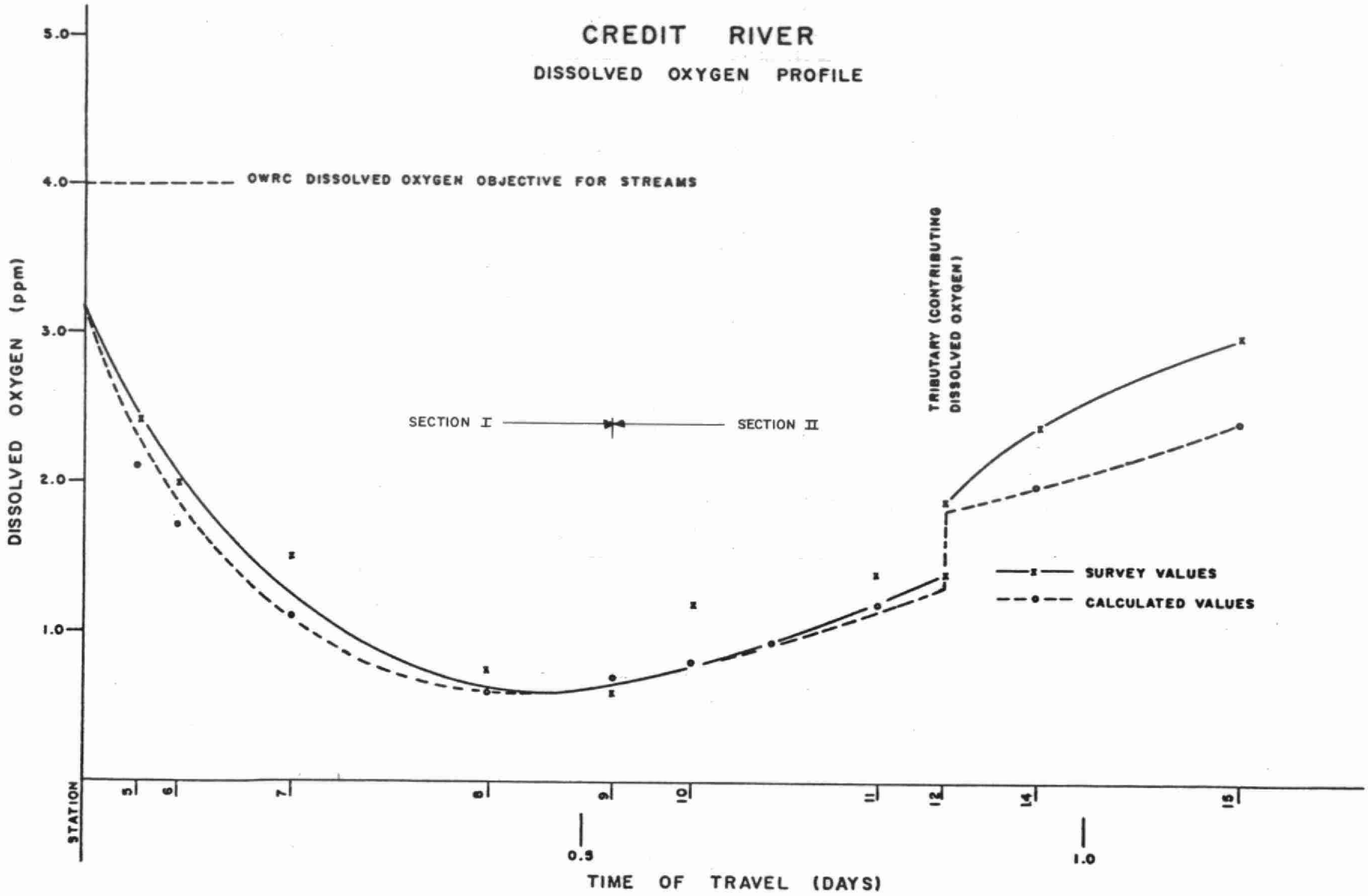
(i) A minimum dissolved oxygen concentration of 65% saturation in the stream above the WPCP discharge. It is emphasized that this concentration cannot be expected to occur until the beaver dam upstream from Station 2 is removed. Decomposing organic matter had depleted almost entirely the dissolved oxygen in the impounded water.

(ii) A minimum dissolved oxygen concentration of 4.0 ppm in the WPCP waste discharge.

(iii) A water temperature of 25°C. At this temperature Kr=Kd=1.00 per day and K_2 = 0.80 per day.

(iv) (a) unaugmented drought flow conditions.
     (b) augmented drought flow conditions.

FIGURE III - 2


CREDIT RIVER
DISSOLVED OXYGEN PROFILE
DISSOLVED OXYGEN (ppm)
5.0
4.0
3.0
2.0
1.0
OWRC DISSOLVED OXYGEN OBJECTIVE FOR STREAMS
SECTION I
SECTION II
TRIBUTARY (CONTRIBUTING DISSOLVED OXYGEN)
SURVEY VALUES
CALCULATED VALUES
STATION
5
6
7
8
9
10
11
12
14
15
0.5
1.0
TIME OF TRAVEL (DAYS)

(a) UNAUGMENTED DROUGHT FLOW CONDITIONS

Under these conditions, a total organic load of 72 pounds per day BOD_5 would satisfy the water quality objective of 4.0 ppm dissolved oxygen and produce an initial BOD_5 concentration of 4 ppm downstream from the plant outfall.

Upstream BOD_5 sources, probably natural, account for 10 pounds per day at the plant. Thus, under present conditions, the plant loading should be restricted to 62 pounds per day BOD_5. A major reduction in the plant output is presently required to maintain the stream quality, as a loading rate of 220 pounds per day was measured at the survey.

For the immediate future, expansion of the plant to 0.75 mgd full secondary treatment implies that it must be operated at a reliable 95 per cent efficiency (raw sewage strength average 156 ppm in 1966), to satisfy this loading limit.

(b) AUGMENTED FLOW CONDITIONS

The Credit River Valley Conservation Authority has proposed the construction of a reservoir north of Orangeville designed primarily for flow augmentation. Tenders for the construction of a dam were recently approved by the Conservation Authorities Branch, Department of Energy and Resources Management. With the completion of the water conservation project expected in late 1969, a reliable summer flow of 10 cfs is expected. The added flow would increase the river's ability to assimilate wastes as illustrated by the following:

PLANT CAPACITY	AUGMENTED STREAM FLOW cfs	ACCEPTABLE BOD_5 LOAD (lbs/d) TO THE STREAM FOR MINIMUM D.O. OF	
		4 ppm	5 ppm
0.75 MGD	5	110	40
	10	200	90
1.5 MGD	5	130	*
	10	225	93

* Dissolved oxygen in stream after initial dilution less than 5.0 ppm.

It should be noted that streamflows of 5 cfs and 10 cfs contribute 30 and 60 pounds of BOD_5 per day respectively. These should be added to the acceptable loading to the stream for calculating the allowable total stream loadings.

It is seen that an increase in the river flow of 100 per cent greatly improves the acceptable treated waste loading rate. Also, at the augmented flow rate of 10 cfs, it becomes possible to achieve the 5.0 ppm dissolved oxygen level believed desirable for game fish.

6. FUTURE CONDITIONS

Proctor and Redfern, Consulting Engineers, in a report on future Orangeville sewage works needs predict that within 10 years the Orangeville WPCP should be enlarged to a 1.5 mgd activated sludge plant.

Completion of the reservoir and the provision of a reliable summer stream flow rate of 10 cfs would permit the extension of the plant to 1.5 mgd, providing the plant is designed and operated to achieve the stream dissolved oxygen objective of 5.0 ppm. This would be accomplished by limiting the BOD_5 loading to about 90 pounds per day.

7. CONSIDERATIONS FOR THE FUTURE

The nitrogen content of the stream was excessive for approximately three miles downstream from the Orangeville WPCP. Phosphorus concentrations remained high throughout the entire survey area. The magnitude and effects of nutrient materials found during the survey are outlined in Appendix A.

With the expected population increase in the Orangeville area, the addition of nutrients to the Credit River will increase. Other natural and man-made sources will continue to add to this input. The nutrients are already at a level to warrant serious consideration of tertiary treatment. With further downstream development and increasing demands for high quality water, this higher degree of treatment will become a definite requirement.

CHAPTER IV

BIOLOGICAL SURVEY

CHAPTER IV

BIOLOGICAL SURVEY

INTRODUCTION

Aquatic communities both in composition and productivity are affected by pollution. The use of biological parameters to indicate past environmental conditions, even of brief duration, renders a valuable adjunct to the assessment of pollution. Emphasis is placed on the plant and animal community as a whole rather than on the presence or absence of certain species. Generally, the community in organically enriched waters is composed of large populations of reduced numbers of species; those species surviving are scavengers adapted to living in reduced oxygen tensions. Deoxygenation, toxicity, and other factors may have acute effects which visibly alter the community, although the cumulative physiological effects of sub-lethal doses are likely to be of more significance. The degree of upset of the biological balance reflects the extent to which properties of the water have been changed. This is the principle of biological detection and assessment of pollution.

The biological survey of the upper Credit River was carried out in August 1965. The community was sampled above as well as below a discharge of wastewater. Sampling sites were selected in a typical habitat with respect to similarities in hydrologic characteristics and nature of the bottom materials.

METHODS

Sampling of invertebrate and fish communities was carried out at 10 stations - one above Orangeville, 5 downstream to the Forks, one on each stream below Erin and Alton and two at and just below the Forks. (Figure IV-1).

Bottom fauna and fish were sampled as follows:

Bottom fauna

One or two collections each consisting of 20 minutes of effort in all common habitats with a 20-mesh (per inch) sieve was made at each station. One collection was made where the habitat was entirely pool or riffles but, where both pools and riffles were found, two separate collections were made. However, only one collection from each station was selected for use in making comparisons among stations.

Fish

One general collection was made at each station. The catch in several seine hauls provided data on the common species at each station and their relative abundance. Trout were returned to the streams.

BIOLOGICAL ASSESSMENT OF WATER QUALITY

The effluent from the Orangeville WPCP comprised approximately one-tenth of the flow in the upper Credit at the time of the survey. The bottom fauna community was composed mainly of tolerant sludgeworms and midges at Station B located 1/2 mile below the plant. However, one species each of moderately intolerant damselfly and mayfly also were present. The bottom fauna community was similar at Stations C and D, although damselflies and mayflies were not found at Station C and one amphipod was collected. Table IV-1 illustrates the similarity of Stations B, C, D, and provides a comparison with Station A located above the treatment plant outfall. The main difference noted above and below the outfall was in the respective small and large numbers of sludgeworms and midges. Because of its level gradient and sluggish nature the stream supports only a limited number of invertebrate species between Stations A and D. However, excessive organic enrichment was evident from the outfall to Station D, with little evidence of improvement through that particular stretch of river.

A marked improvement in water quality was indicated at Station E below the Orangeville Golf Course pond. Mayflies, caddisflies and amphipods were numerous while sludgeworms and midges were very much reduced (Table IV-1). The increase in stream gradient and occurrence of riffle areas was mainly responsible for the change in bottom fauna. However, the character of the bottom fauna at Station E indicated good water quality over the past several months.

Collections at Stations G, I and J further downstream included a variety of intolerant species of caddisflies, mayflies and stoneflies and indicated good water quality.

The number of bottom fauna forms and number of individuals collected at each station on the main branch are shown in Figure IV-I. The temporary reduction in number of forms below the outfall and downstream recovery is evident.

Differences in bottom fauna among the stations on the main branch may be compared with water quality, particularly dissolved oxygen. The concentration of dissolved oxygen was low at Stations C and D in comparison with Station A (Table IV-2). Similar, but more severe quality conditions were encountered during the July, 1966 wastewater assimilation study (Appendix A). Oxygen levels were greater one mile above Station E and were quite satisfactory 1/2 mile below. BOD decreased over the same stretch of stream from Station C to Station E, as did all of the nitrogen and phosphorus fractions which were measured. The levels of nutrients, phosphorus and nitrogen, were initially quite great but reduced further downstream. The effects of enrichment were evident in large standing crops of bottom animals notably at Stations G and I.

A variety of invertebrates was collected at Station F below Alton on the Alton branch tributary to the upper Credit. The presence of several intolerant and moderately intolerant froms provided evidence that pollution from Alton, if any, must be quite limited in amount and effect. Similarly, the collection at Station H demonstrated that the west branch of the upper Credit was in excellent condition below Erin.

Qualitative collections of fish add further to the biological assessment of water quality in the upper Credit River. The stream north of Orangeville had a fish popultation of a limited number of species adapted to this sluggish, bog-stream habitat including the mud minnow, redbelly dace, brook stickleback, blacknose shiner and white sucker. No fish were taken at Station B, possibly because of the low average concentration of dissolved oxygen. Further downstream at Stations C and D most of the above species were collected. The mud minnow, redbelly dace and sucker are among the fish most tolerant of organic contamination. The white sucker was particularly abundant probably because of the large population of midge larvae there.

The composition of the fish population was quite different in the more rapid waters at Station E and downstream to Station J. The creek chub, blacknose dace, longnose dace and white sucker were abundant. The dace are probably only moderately tolerant of organic contamination. Several brook trout were netted and returned to the water at Station G.

Fish populations on the Alton branch and west branch appeared to be quite normal. Trout were observed at Station H.

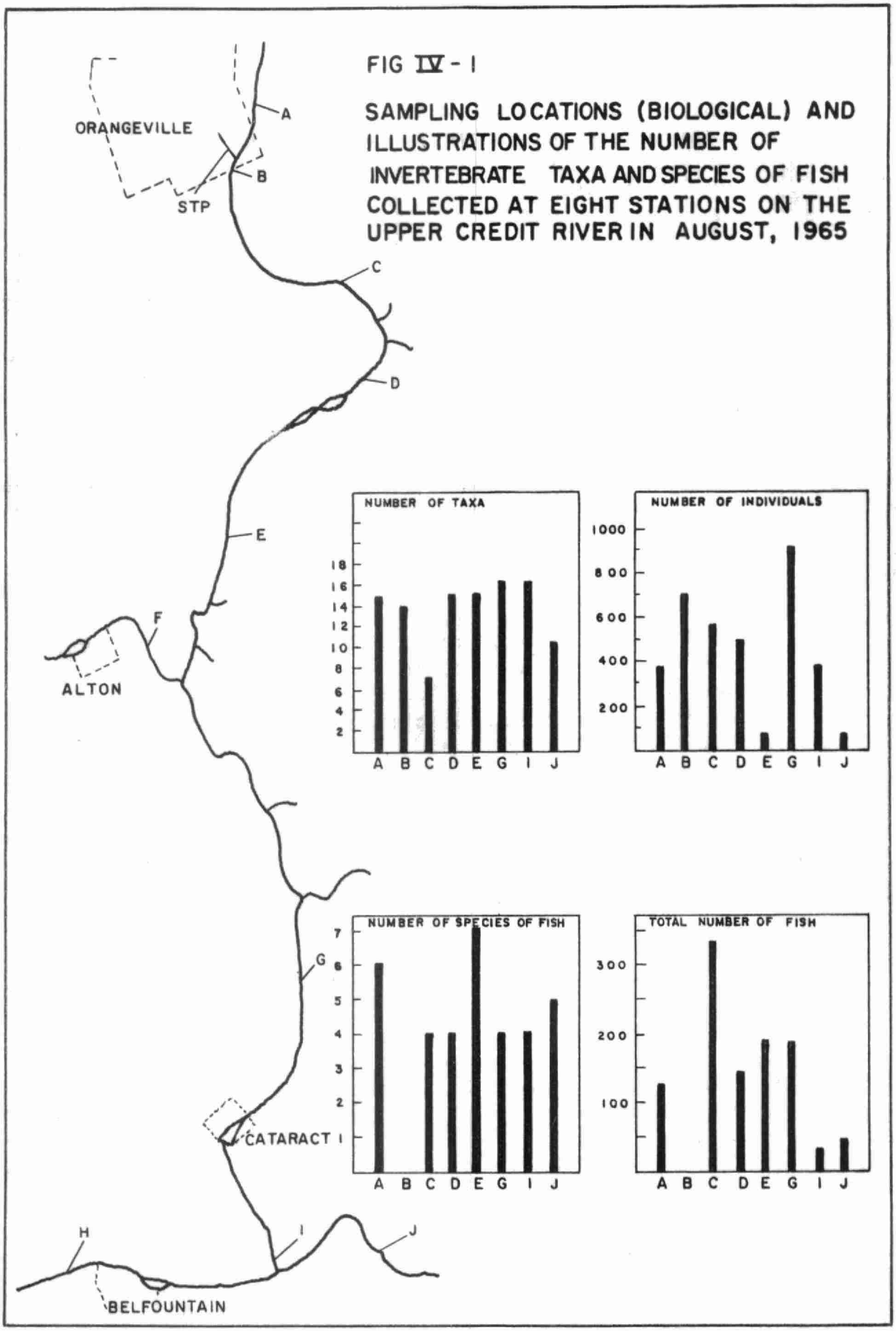


FIG IV - I

SAMPLING LOCATIONS (BIOLOGICAL) AND ILLUSTRATIONS OF THE NUMBER OF INVERTEBRATE TAXA AND SPECIES OF FISH COLLECTED AT EIGHT STATIONS ON THE UPPER CREDIT RIVER IN AUGUST, 1965

TABLE IV-1. Numbers of animals collected of the common groups of invertebrates arranged in order of decreasing tolerance to organic pollution. Station A was located upstream from the Orangeville sewage treatment plant and the others were located in sequence on the main branch downstream to the Forks.

increasing tolerance

Station	Tubificids	Midges	Leeches	Beetles*	Dragonflies Damselflies	Amphipods	Caddisflies	Mayflies	Stoneflies
A	0	2	1	0	10	3	1	1	0
B	280	362	3	21	15	0	0	2	0
C	14	526	0	1	0	1	0	0	0
D	24	333	4	44	24	0	0	12	0
E	1	20	5	0	0	13	39	8	0
G	2	63	0	0	0	0	114	577	2
I	0	55	0	1	0	1	188	106	0
J	0	7	0	0	0	2	8	4	3

* larvae beetles only

Note: For station location see Fig. IV-1.

TABLE IV-2 Chemical characteristics of water in the Upper Credit River during the period July 26 to 28, 1965. Data on solids, phosphorus and nitrogen fractions are means of four analyses; data on dissolved oxygen and BOD are means of 12 observations. All data were provided by the Water Quality Surveys Branch.

Station*	Dissolved Oxygen			Biochemical Oxygen Demand	Solids		Phosphorus		Nitrogen			
	Min.	Max.	Mean		Susp.	Diss.	Sol.	Total	NH_3	TKN	NO_2	NO_3
A	4.0	10.7	6.5	1.3	16	335	0.2	0.2	0.1	0.5	-	.19
C	0.8	4.4	1.8	2.8	10	430	4.1	6.2	2.1	3.0	.02	.15
D	0.8	10.6	4.7	4.6	21	368	2.9	3.6	0.2	1.4	.03	.69
1 mile above E	5.8	18.0	8.4	3.7	21	349	2.5	3.3	0.3	0.9	.02	.23
1/2 mile below E	5.6	12.8	8.7	3.1	46	350	1.9	2.6	0.1	0.9	.01	.19

* Biological Survey Stations
FIGURE IV - 1

All parameters reported in ppm.

CHAPTER V

SUMMARY AND DISCUSSION

SUMMARY AND DISCUSSION

A detailed wastewater assimilation study carried out in July, 1966 revealed that the organic and nutrient loadings from Orangeville deteriorated water quality in the Upper Credit River beyond acceptable limits. The dissolved oxygen was depleted and maximum BOD_5 values as high as 39 ppm were encountered in the river. These findings were supported by the results of a biological study, despite the fact that the biological sampling stations were not located in the critical reach immediately downstream from Orangeville. The complete absence of fish substantiates the lack of sufficient dissolved oxygen and the loss of this river section in its use for sport fishery.

The mathematical model used for the prediction of an acceptable organic loading in the Credit River at Orangeville is predicated on the conditions that the beaver dam upstream from the WPCP be removed. Dissolved oxygen levels in these impounded waters were found to be negligible, thereby seriously restricting the discharge of an acceptable organic load to the watercourse. The removal of the beaver dam is assumed to raise the upstream dissolved oxygen to 65 per cent saturation. Under unaugmented flows and an assumed minimum downstream dissolved oxygen concentration of 4.0 ppm, the allowable loading from the plant would be in the order of 60 pounds per day. This loading limitation is required only until the proposed reservoir upstream from Orangeville is operational (probably in late 1969). At that time, a reliable streamflow of 10 cfs should be available during summer months. Under these conditions the loading to the stream should be limited to 90 pounds per day to achieve a dissolved oxygen objective of 5.0 ppm. The proposed extension of the Orangeville plant to 1.5 mgd should take the above loading limitation into account.

The Orangeville municipal wastewater discharge contained significant nitrogen and phosphorous concentrations which had promoted extensive algal growth in downstream sections. There are plans for the construction of a reservoir north of Cataract on the main branch of the Credit River and there appears little doubt that Orangeville would contribute considerably to the nutrient enrichment of such an impoundment. Serious consideration should be given to the removal of nutrients from the Orangeville municipal wastewaters to ensure full benefits of any future downstream multiple-use reservoir.

APPENDIX A

FIELD OBSERVATIONS AND DISCUSSION OF SURVEY DATA

TEMPERATURE

DISSOLVED OXYGEN

BIOCHEMICAL OXYGEN DEMAND

NUTRIENT MATERIALS

SOLIDS

COLIFORM BACTERIA DENSITIES

STREAMFLOW

TIME OF TRAVEL

APPENDIX A

DISCUSSION OF FIELD AND LABORATORY DATA

TEMPERATURE

The average temperature from station to station remained fairly constant throughout the survey area.

Summary of Temperature Data (°C)

Station	Average	Maximum	Minimum
1	20	-	-
2	20.1	21	17.5
WPCP	16.5	17	16
3	17.1	19	15
4*	11.5	15.5	9.0
5	17.0	19.5	15
5A	20	-	-
6	18.2	21	16
7	18.8	24	13.5
8	18.9	23	13.5
9	18.8	21	16
10	18.5	22	14.0
11	19.9	23	16.0
12	19.5	21.5	16.0
13*	20.9	22.5	18.5
14	19.9	23	16
15	18.6	20.5	14.5

Summary of Temperature Data (^{o}C) cont'd

Station	Average	Maximum	Minimum
16	21.4	25	19
17	19.9	24.5	17.5
18	17.9	21	14.5

* Tributary

DISSOLVED OXYGEN

The dissolved oxygen (DO) concentrations are severely depressed from the upstream stations through to station 15. The low DO of control stations 1, 2 and 5A is attributed to the oxygen demand exerted by bottom sediments found behind the U-shaped beaver dam. On several occasions the stream was found in septic conditions (Stations 7 and 8). The stream recovers between Stations 10 and 16 with DO levels increasing to 70% saturation.

Summary of Dissolved Oxygen Data

Station	DO Concentrations (ppm)			Average DO Deficit	
	Ave.	Max.	Min.	ppm	lbs/day
1	2.6	-	-	6.6	86.4
2	1.4	2.2	0.0	7.8	8.4
WPCP	4.0	4.3	3.6	5.9	25.5
3	3.4	4.0	2.7	6.3	34.6
4*	6.5	8.4	4.4	4.6	5.0
5	2.4	3.0	1.4	7.3	47.4
5A	1.1	-	-	8.7	100
6	2.0	3.4	0.8	7.5	142
7	1.5	3.4	0.0	7.9	149

Summary of Dissolved Oxygen Data Cont'd

Station	Ave.	Max.	Min.	ppm.	lbs/day
8	0.75	2.9	0.0	8.6	162.5
9	0.6	1.5	0.2	8.8	166
10	1.2	2.9	0.5	8.2	155
11	1.4	2.8	0.8	7.8	147
12	1.4	4.0	0.2	7.9	149
13*	7.9	8.6	7.4	1.1	1.8
14	2.4	4.6	0.9	6.8	139
15	3.0	6.0	0.4	6.4	133
16	6.4	9.4	4.6	2.5	36.7
17	5.9	7.5	3.2	3.3	98
18	7.0	8.9	5.0	2.6	102

* Tributaries

OWRC Dissolved Oxygen stream objectives - 4.0 ppm.

BIOCHEMICAL OXYGEN DEMAND

An analysis of the collected BOD data reveals a substantial increase in BOD_5 levels downstream from Orangeville after the introduction of the municipal WPCP load. BOD_5 levels exhibit a marked decreasing trend to Station 9, a slight increase at Stations 10 and 11 and a continuous decreasing trend to station 18. The increase at Station 10 and 11 may be attributed to algae respiration in the incubated BOD test bottles. No verification of this theory could be obtained at this time. A greater amount of algae was observed at these two stations than at others.

Summary of BOD Data

Station	Average BOD_5		Maximum	Minimum
	ppm	lbs/day	ppm	ppm
1	.55	7.2	-	-
2	3.4	3.7	4.8	0.4
WPCP	50	219	68	19
3	41.1	222	61	18
4*	0.6	0.6	2	0.2
5	29.1	189	39	9.0
5A	3.0	37.3	-	-
6	7.2	136	16	3.0
7	5.8	110	11	3.0
8	4.4	83	5.8	2.9
9	2.6	49.2	4.0	1.4
10	4.0	75.5	6.4	2.3
11	5.1	96.4	10	1.9
12	3.7	70.0	5.5	2.4
13*	0.9	1.5	2.5	0.3
14	2.1	43.1	3.4	1.0
15	1.7	35.3	4.1	0.3
16	1.7	36.7	5.2	0.7
17	1.3	38.6	3.0	0.7
18	1.1	43	1.7	0.6

* Tributaries

OWRC BOD_5 objectives in streams - 4.0 ppm.

NUTRIENT MATERIALS

Domestic sewage contains a significant amount of protein matter which is relatively rich in organic nitrogen (total Kjeldahl and ammonia) and phosphorus compounds. Modern sewage treatment methods including the activated sludge process are relatively inefficient in removing these materials.

Nitrogen and phosphorus compounds are necessary for plant growth. However, excessive nutrient quantities may accelerate the aquatic plant growth under suitable environmental conditions. Excessive aquatic growth, in turn, can seriously deplete oxygen reserves when the photosynthetic (oxygen producing) process is reversed during the night hours.

Phosphorus and nitrogen nutrients occurred in high concentrations downstream from the WPCP to station 15 causing profuse aquatic growth in the stream. A considerable amount of organic nitrogen is stabilized in the pond between stations 15 and 16 (time of travel - 5.0 days). However, no coinciding appreciable reduction in phosphorus levels was noted in this stretch.

Summary of Nitrogen & Phosphorus Data

One Grab Sample Only

Station	Total Kjeldahl (ppm)	Ammonia (ppm)	Nitrite (ppm)	Nitrate (ppm)	Total Phosphorus (ppm)	Soluble Phosphorus (ppm)
1	0.03	0.2	0.01	0.3	0.06	0.06
2	0.22	1.4	0.01	0.1	0.39	0.17
WPCP	18.0	23.2	0.9	0.7	17.5	12.2
3	16.4	26.4	1.0	0.5	12.2	3.2
4*	0.06	0.20	0.02	2.50	0.12	0.12
5	16.4	23	0.8	0.6	10.4	9.6
5A	0.11	2.2	0.0	0.11	1.9	0.97
6	-	-	-	-	-	-
7	4.27	6.6	0.06	0.05	5.3	5.0

Summary of Nitrogen & Phosphorus Data Cont'd

Station	Total Kjeldahl (ppm)	Ammonia (ppm)	Nitrite (ppm)	Nitrate (ppm)	Total Phosphorus (ppm)	Soluble Phosphorus (ppm)
8	4.92	23.5	0.0	0.01	6.2	5.8
9	4.1	6.1	0.06	0.03	7.9	6.5
10	3.44	4.1	0.01	0.03	5.8	5.7
11	3.28	3.8	0.05	0.05	5.7	5.6
12	2.78	3.4	0.03	0.15	5.0	4.8
13*	0.13	0.33	0.02	0.5	0.03	0.01
14	2.46	2.7	0.05	0.16	4.6	4.4
15	1.05	1.4	0.1	0.25	4.0	3.9
16	0.06	0.71	0.05	0.15	3.52	3.4
17	0.05	0.46	0.04	0.04	4.9	3.8
18	0.03	-	0.02	0.5	2.44	2.28

* Tributary

Concentrations that may initiate nuisance algal growth:

Inorganic nitrogen as N (nitrites and nitrate) - 0.28 ppm.

Soluble phosphorus as P - 0.01 ppm.

SOLIDS

In general, total, suspended and volatile solids decreased uniformly downstream from Orangeville. The increase of solids at Station 9 may be attributed to the scouring action of the stream water flowing over the beaver dam just upstream of the station.

Summary of Solids Concentrations

(One Grab Sample Only)

Station	Total Solids ppm	Suspended Solids ppm	Volatile Suspended Solids ppm
1	348	4	4
2	340	80	65
WPCP	663	60	35
3	594	27	18
4*	520	3	2
5	592	38	25
5A	352	20	10
6	-	-	-
7	554	81	30
8	448	10	8
9	554	116	19
10	442	22	10
11	422	4	3
12	414	2	1
13*	244	4	3
14	384	23	7
15	380	1	1
16	382	4	2
17	388	8	2
18	368	7	4

* Tributaries

COLIFORM BACTERIA CONTENT

The coliform count downstream of the WPCP indicates that the chlorination of the effluent from the plant was not effective at the time of the survey. A count of 13 million coliforms per 100 ml of sample (station 5) poses a health hazard for a stream running close to urban development. The stream does not recover until it reaches station 10. The sharp increase to 6,000 organisms per 100 ml at station 17 suggest seepage from local septic tanks.

Station	MF Coliform per 100 ml.
1	-
2	6,100
WPCP	-
3	4,600,000
4*	4,000
5	13,000,000
5A	-
6	4,000,000
7	> 150,000
8	89,000
9	13,000
10	580
11	290
12	270
13*	260
14	100
15	130

Station	MF Coliform per 100 ml.
16	80
17	6,000
18	870

* Tributaries

OWRC water quality objectives - less than 2,400 coliform organisms per 100 ml.

STREAMFLOW

Streamflow velocities were measured using a Gurley current meter (Model 622) and streamflow was calculated by the velocity area method.

Summary of Average Streamflows

Station	Drainage Area (sq. mi.)	Flow Average (cfs)
1	15.0	2.4
2	N.A.	0.2
WPCP	N.A.	0.81
3	15.2	1.0
4*	.05	0.2
5	15.3	1.2
5A	-	2.3
6	15.6	3.5
7	17.2	3.5
8	17.7	3.5
9	17.8	3.5
10	18.0	3.5
11	18.1	3.5

Station	Drainage Area (sq. mi.)	Flow Average (cfs)
12	18.2	3.5
13*	1.83	0.3
14	21.2	3.8
15	25.1	3.85
16	27.2	4.0
17	28.1	5.5
18	29.1	7.2

* Tributaries

TIME OF TRAVEL

Summary of Time of Travel

Reach	Point to Point (Days)	Cumulative (Days)
WPCP-5	0.054	0.054
5 - 6	0.040	0.094
6 - 7	0.115	0.209
7 - 8	0.198	0.407
8 - 9	0.125	0.532
9 - 10	0.077	0.609
10-11	0.187	0.796
11 - 12	0.063	0.859
12 - 14	0.094	0.953
14 - 15	0.198	1.15
15 - 16	5.0*	6.2
16 - 17	0.094	6.3
17 - 18	0.312	6.6

* Time of travel obtained by the volume displacement method.

APPENDIX B

DROUGHT FLOW PREDICTIONS

APPENDIX B

DROUGHT FLOW PREDICTIONS

Drought flow predictions for the survey area were made from records kept by the Department of Energy, Mines and Resources. Flows at Cataract provide a 46 year period of records. In Table B-1, the minimum, average, and maximum daily flows as well as the average daily flows for seven and thirty day low flow periods are tabulated. These flows were ranked in descending order, and the frequency of occurrence was calculated using Gumble's Theory of Probability.

Based on these calculations flow (in cfs) versus per cent time equalled or exceeded were plotted on log-probability paper and the flows with a 20, 10 and 5 year return period were obtained as follows:

	Return Period (Years)		
	20	10	5
minimum daily low flow	9.3	10.5	12.2
7-day average low flow	10.5	12	13.8
30-day average low flow	13.5	15	17

(Note: All flows in cfs)

The 20 year return period flows per square mile for Cataract (drainage area 82.0 sq. mi.) were calculated to be as follows:

minimum daily flow	0.113 cfs/mi^2
7-day low flow period	0.128 cfs/mi^2
30-day low flow period	0.165 cfs/mi^2

The flow contribution per square mile was assumed to apply to the Upper Credit River basin.

TABLE B-1

SUMMARY OF FLOW RECORDS
CREDIT RIVER NEAR CATARACT STATION #2HB1
Drainage Area - 82 Square Miles

(cfs)

Water Year	Minimum	Average	Maximum	7-day Low Flow	30-day Low Flow
64-65	16.5	58.6	755	20.1	23.5
63-64	14.0	37.6	226	18.3	20.3
62-63	12.0	42.1	585	13.9	15.9
61-62	15.0	35.2	502	16.0	19.3
60-61	22.9	51	510	23.1	26.2
59-60	27.6	72.5	494	29.0	31.7
58-59	17	55	665	21.4	23.4
57-58	12	36	122	12.1	15.7
56-57	20	59	705	20.0	21.2
55-56	30	98	1,470	35.0	41
54-55	26	90	823	29.4	32.9
53-54	24	78	1,030 (e)	24.0	32.0
52-53	14	40	340	14.1	20.0
51-52	18	52	494	18.0	20.9
50-51	14	60	953	14.6	20.0
49-50	14	77	1,750	18	20.4
48-49	11	49	638	11	12.9
47-48	11	56	1,190	11.1	15.8
46-47	11	69	850	11.0	21.6
45-46	11	49	820	14.0	15.5
44-45	18	45	402	18.0	18.0
43-44	11	53	685	11.4	17.0
42-43	18	87	685	22.4	34.3
41-42	18	61	1,190	20.4	22.5
40-41	19	49	464	22.3	24.3
39-40	7	45	580	8	8
38-39	19	56	705	22.7	27
37-38	10	52	473	14.0	16.9
36-37	13	73	790	20.6	23.0
35-36	19	46	-	19.0	20.6
34-35	16	65	660	16.3	18.4
33-34	17	70	730	19.7	22.4
32-33	18	86	-	24.8	28.6
31-32	15	34	280	15.8	17.9
30-31	13	22	-	14.3	16.0
29-30	13	79	1,540	15.1	16.8
28-29	16	60	765	25.1	27.0
27-28	15	77	1,200	22.3	24.0

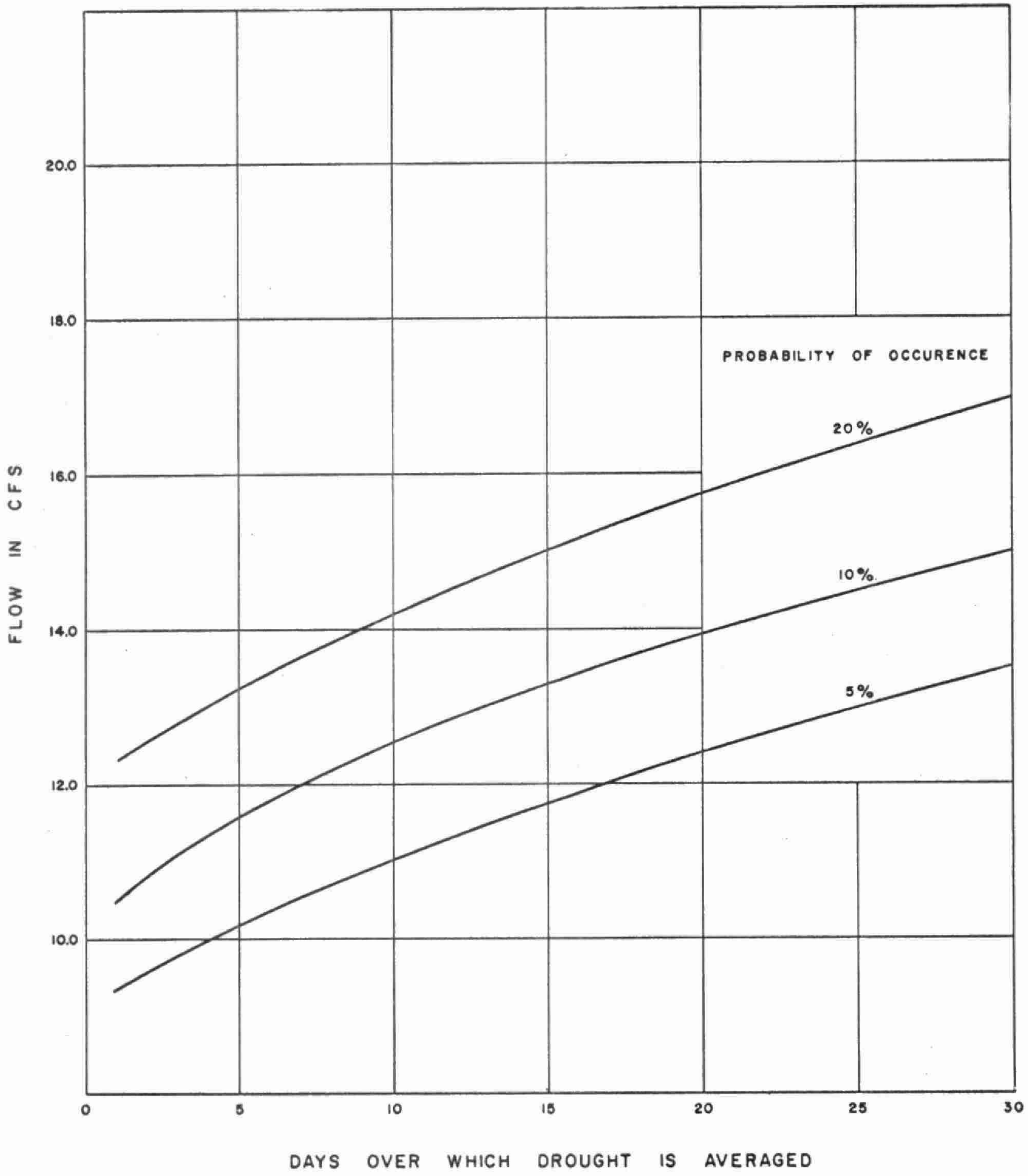
Water Year	Minimum	Average	Maximum	7-day Low Flow	30-day Low Flow
26-27	19.0	62	1,120	21.3	24.4
25-26	12	47	1,690	13.8	17.1
24-25	14	55	540	17.1	19.3
23-24	12	56	1,160	14.0	15.0
22-23	15	60	665	19.8	22.9
21-22	20	54	800	23.1	25.2
20-21	12	55	1,240	12.6	13.9

FIGURE B-1

CREDIT RIVER

CATARACT GAUGE

DROUGHT DURATION VS. SEVERITY



APPENDIX C

WASTE ASSIMILATION FORMULAE

APPENDIX C

WASTE ASSIMILATION FORMULAE

The following briefly outlines the formulae used in the waste assimilation calculations and the significance of the terms employed.

D_o = the dissolved oxygen deficit at the point of pollution or the point of reference.

D_t = the deficit at any point distant time t (in days) from the reference point.

L_o = the first stage BOD at the point of reference.

K_r = $2.3\ k_r$ = coefficient of BOD removal.

K_d = $2.3\ k_d$ = coefficient of deoxygenation.

K_2 = $2.3\ k_2$ = coefficient of reoxygenation.

t = time of travel (days).

t_c = time of travel to the minimum point of the oxygen sag curve.

With known values of D_o, L_o, K_r, K_d, and K_2, the oxygen deficit (D) may be computed for any time (t) downstream by the following equation:

$$D = \frac{K_d L_o}{K_2 - K_r} \left(e^{-K_r t} - e^{-K_2 t}\right) + D_o e^{-K_2 t}$$

Using D, the dissolved oxygen is calculated and plotted as a continuous curve against time to form the oxygen profile. (Figure III-2).

The complete solution of the sag curve is time-consuming and since in many cases the critical point and its ordinate, the critical time, t_c, and the critical depletion, D_c, are of interest only, the following formula for calculating t_c is used.

$$t_c = \frac{1}{K_2 - K_r} \quad \ln \frac{K_2}{K_r} \left[1 - \frac{D_o}{L_o} \; \frac{(K_2 - K_r)}{K_d} \right]$$

The coefficient of reoxygenation (K_2) is established using the average depth and velocity of a stream cross-section.

$$K_2 = \frac{(D_L \;\; V)^{1/2}}{H^{3/2}} \qquad \text{(Base e)}$$

Where

D_L = Oxygen diffusivity coefficient - 0.81×10^{-4} sq. ft/hour at 20°C.

V = Average velocity in feet per hour.

H = Average depth in feet.

APPENDIX D

ABBREVIATIONS

APPENDIX D

ABBREVIATIONS

mgd	-	million gallons per day (Imperial)
BOD_5	-	5-Day Biochemical Oxygen Demand
°C	-	degrees Centigrade
°F	-	degrees Fahrenheit
Ft.	-	feet
WPCP	-	Water Pollution Control Plant
ppm	-	parts per million
cfs	-	cubic feet per second
cfs/sq.mi.	-	cubic feet per second per square mile
%	-	percentage
lbs	-	pounds
M.F.	-	Membrane Filter
>	-	greater than
DO	-	dissolved oxygen
lbs/d	-	pounds per day